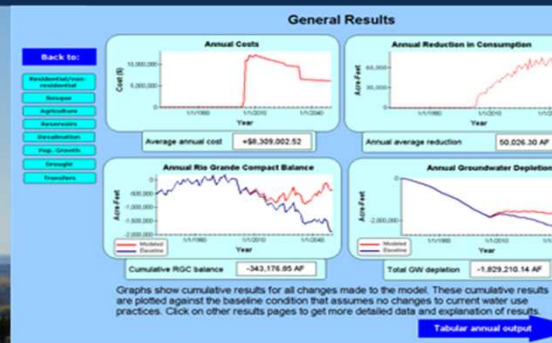


*Exceptional service in the national interest*



# Energy-Water Nexus: Challenges and Opportunities

*Vincent Tidwell*

*Sandia National Laboratories*

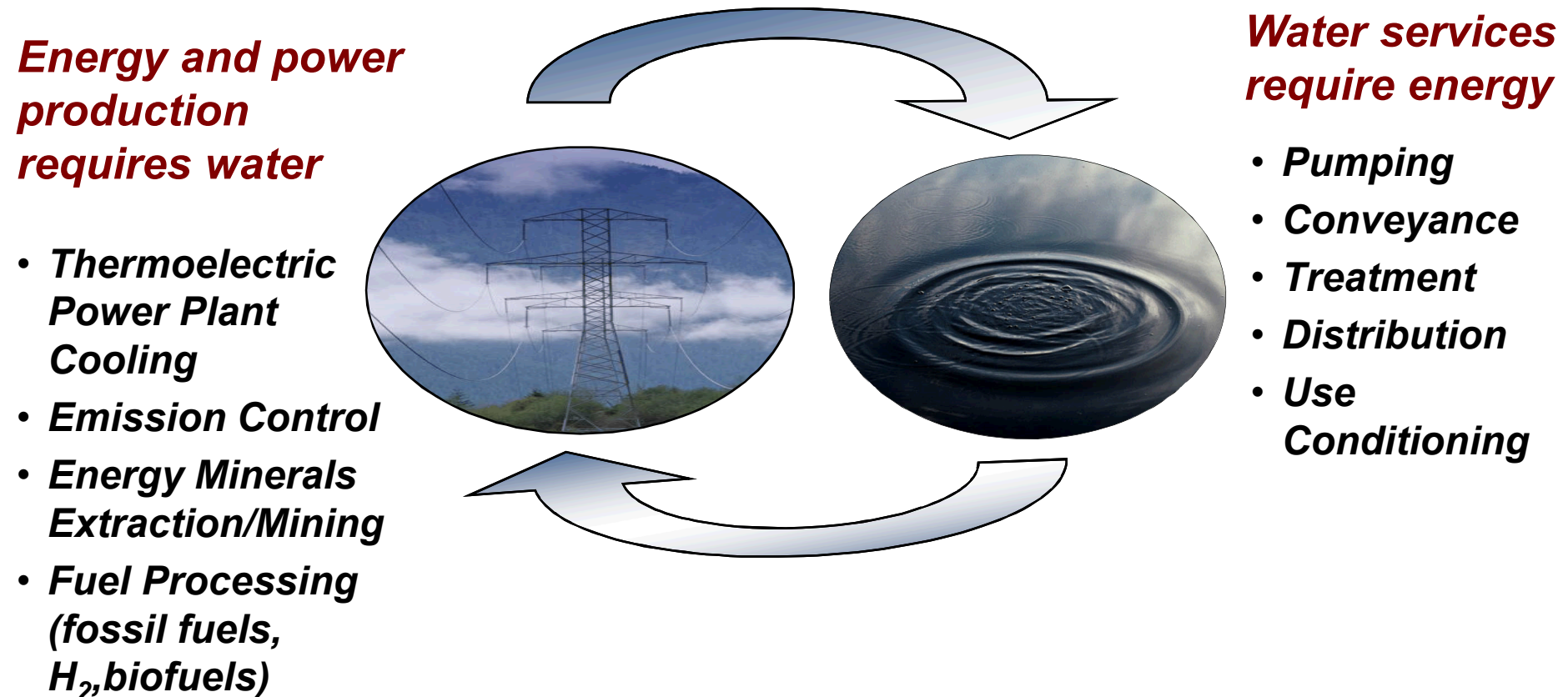
*NM SPE E-Week*

*February 26, 2016*



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

# Energy-Water Nexus



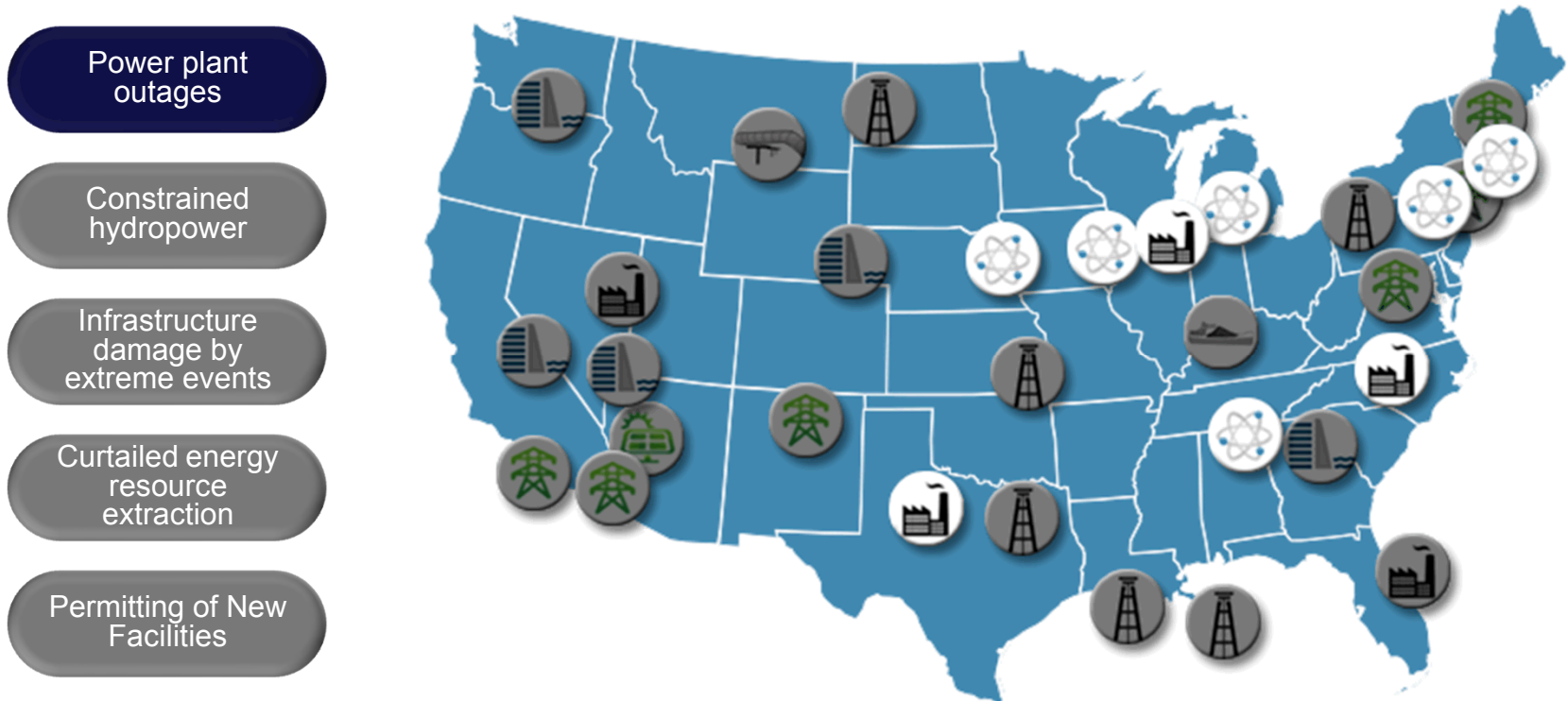
# Energy-Water Nexus

“Many times in recent years, water use practices proposed for new energy conversion facilities have been the subject of great controversy. Many people anticipate that the frequency and bitterness of these conflicts will increase.”

**(DOE, 1980)**

# Impacts Today

## Energy-Water-Climate Nexus

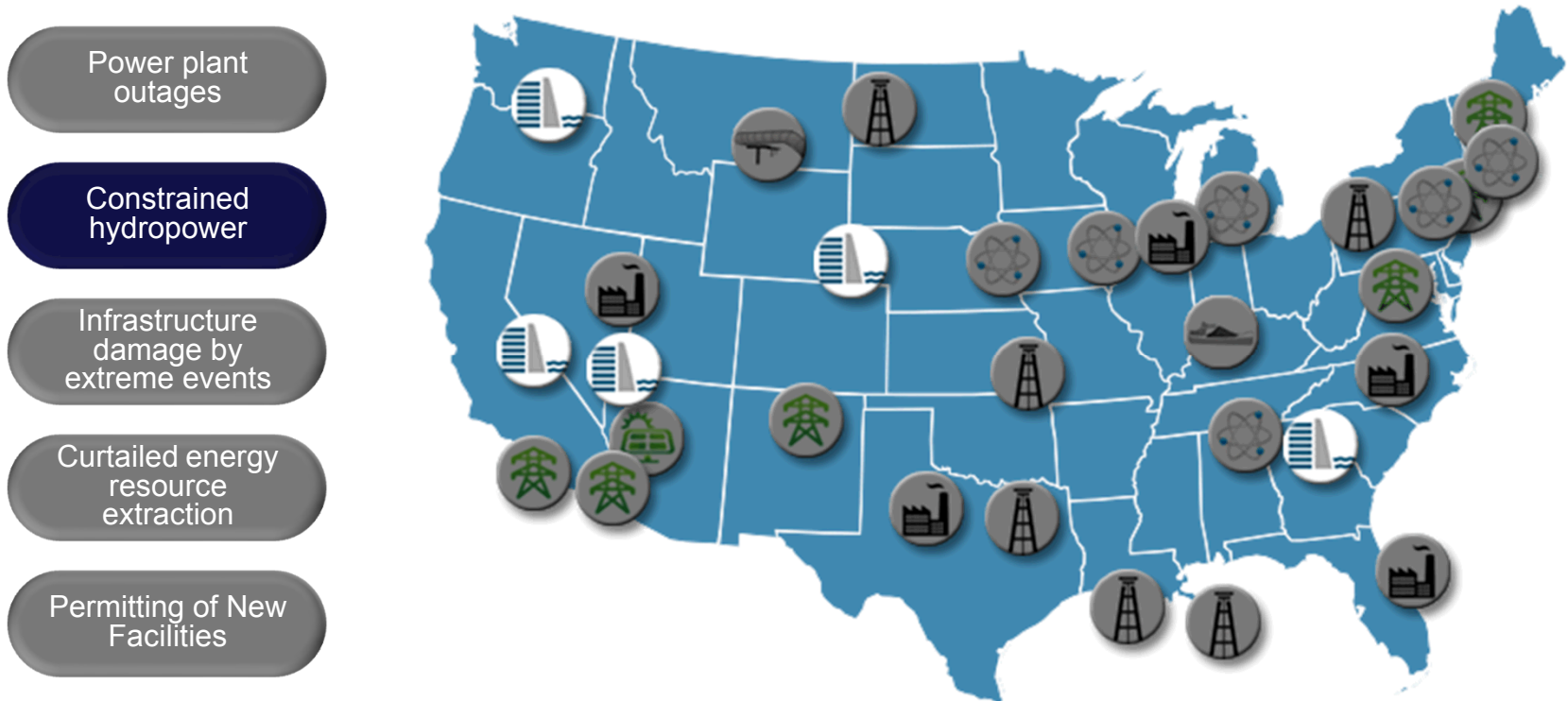


Climate Change, Water Scarcity and Competing Demands  
are Impacting Energy Security NOW



# Impacts Today

## Energy-Water-Climate Nexus



Climate Change, Water Scarcity and Competing Demands  
are Impacting Energy Security NOW

# Impacts Today

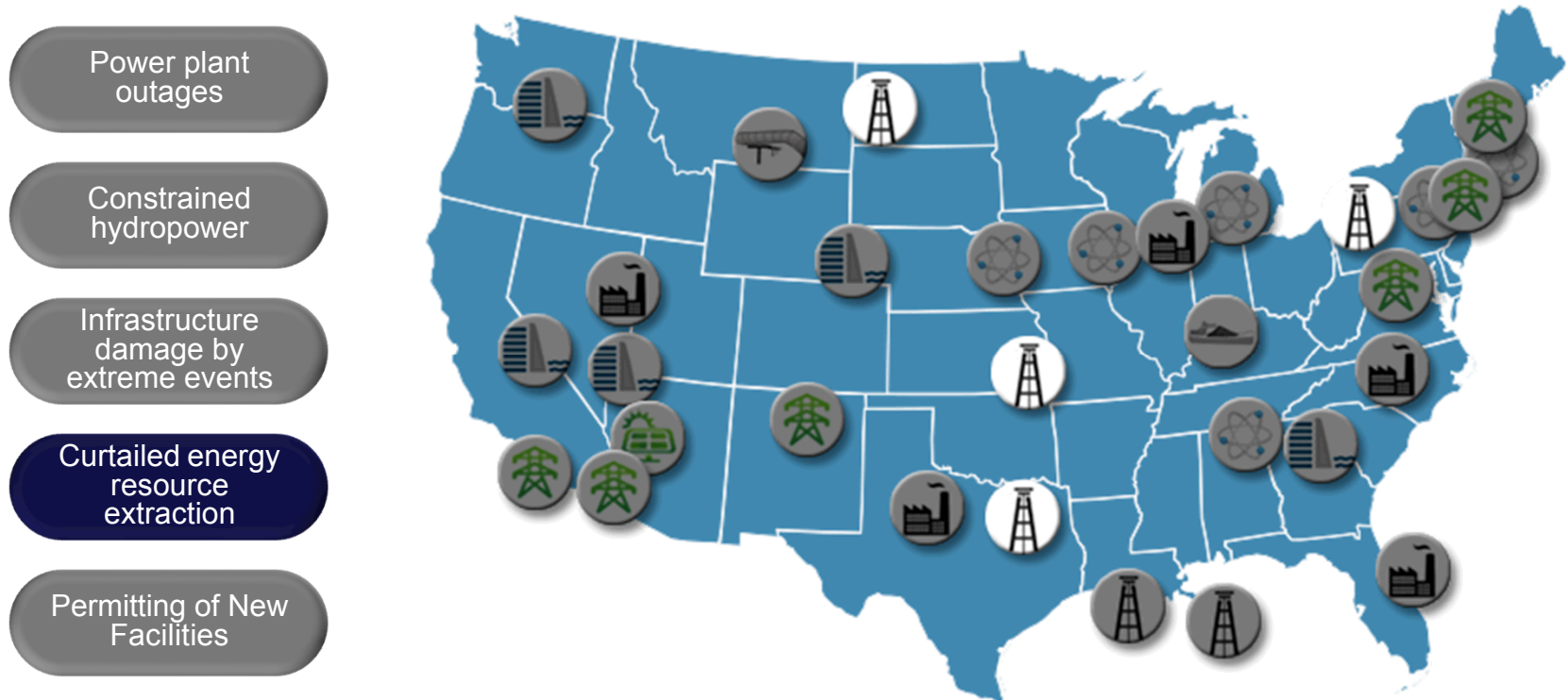
## Energy-Water-Climate Nexus



Climate Change, Water Scarcity and Competing Demands  
are Impacting Energy Security NOW

# Impacts Today

## Energy-Water-Climate Nexus



Climate Change, Water Scarcity and Competing Demands  
are Impacting Energy Security NOW

# Impacts Today

## Energy-Water-Climate Nexus



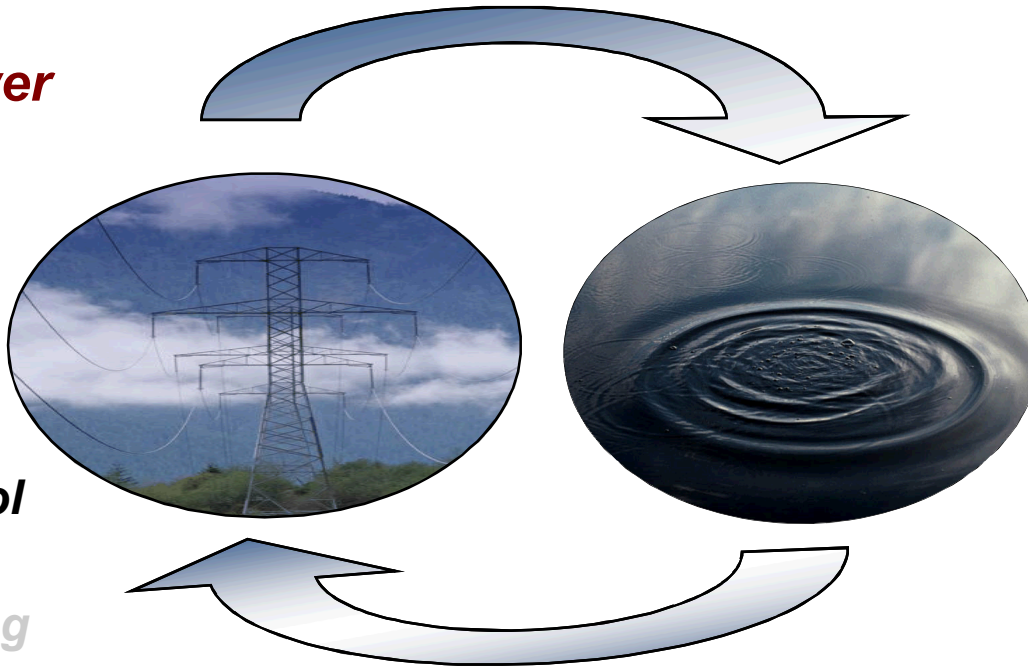
Climate Change, Water Scarcity and Competing Demands  
are Impacting Energy Security NOW

***Energy-  
Water  
Nexus  
Present***

# Energy-Water Nexus

## **Energy and power production requires water**

- **Thermoelectric Power Plant Cooling**
- **Emission Control**
- *Energy Minerals Extraction/Mining*
- *Fuel Processing (fossil fuels, H<sub>2</sub>, biofuels)*

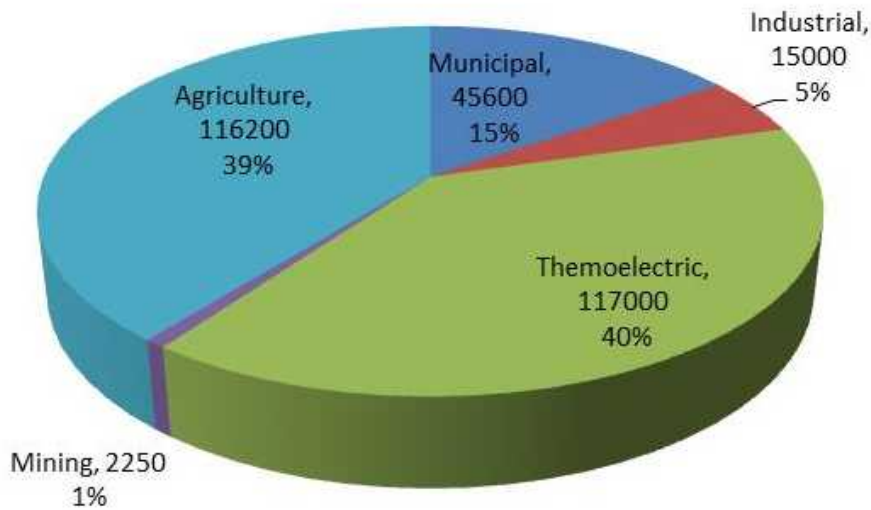


## **Water services require energy**

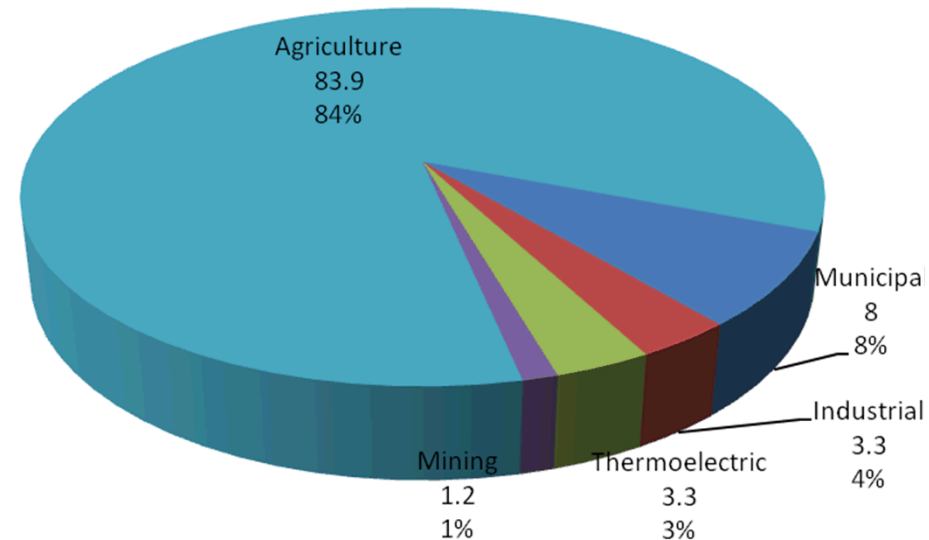
- *Pumping*
- *Conveyance*
- *Treatment*
- *Distribution*
- *Use Conditioning*

# Water for Thermoelectric Power Generation

## Water Withdrawal (BGD) 2010



## Water Consumption (BGD) 1995

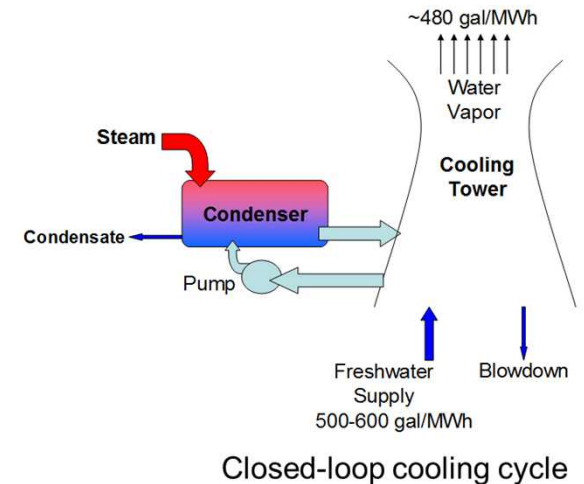
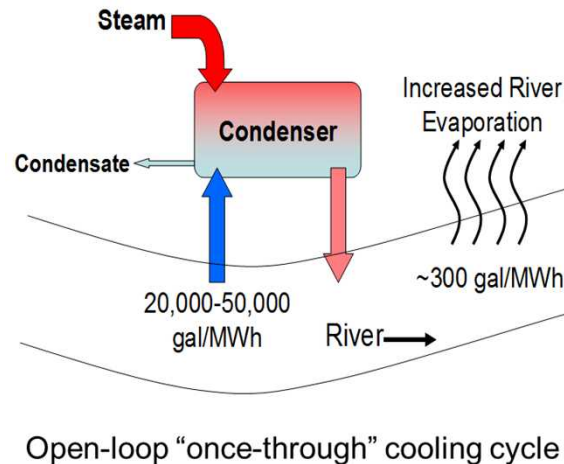


Source: USGS 1995, 2014

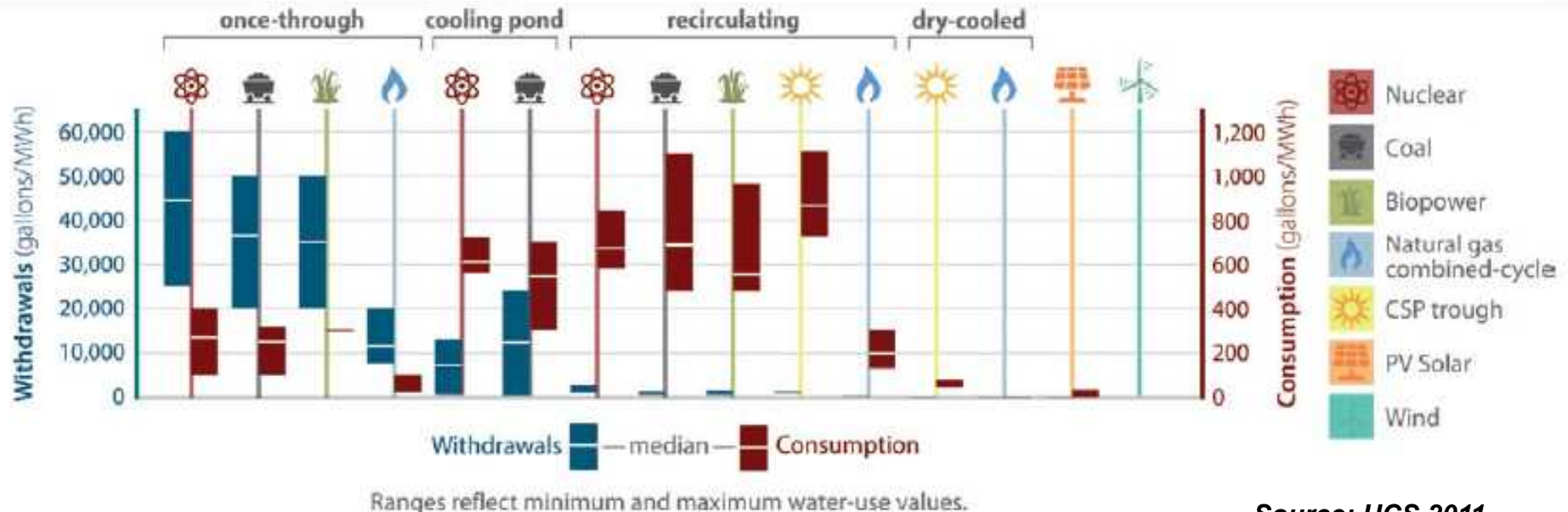


# Water for Thermoelectric Power

- Water use influenced by:
  - Fuel type,
  - Cooling type,
  - Emission controls,
  - Age, and
  - Location



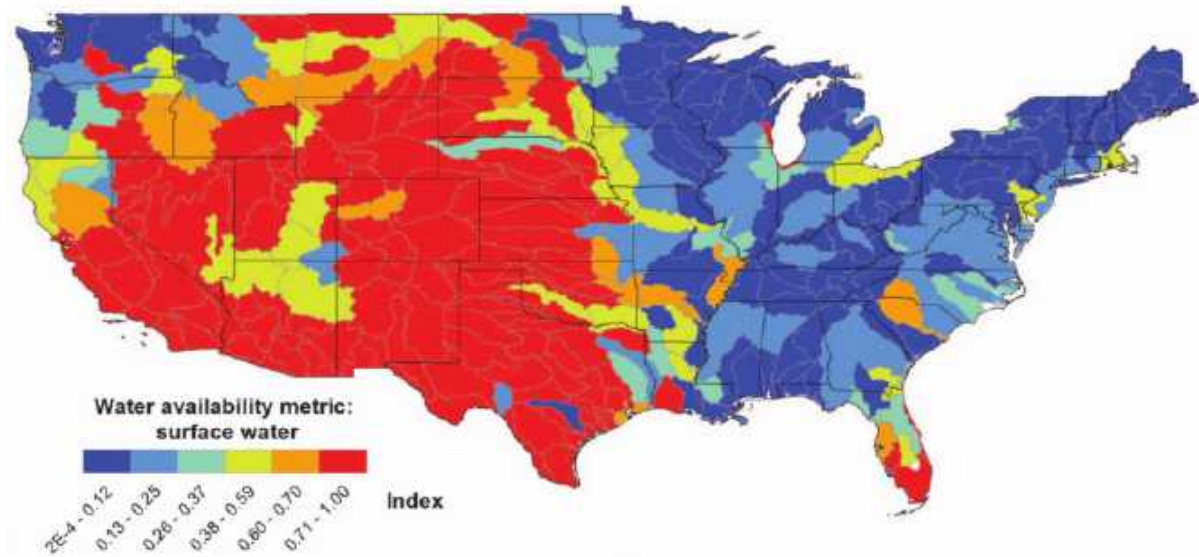
Source: EPRI 2002



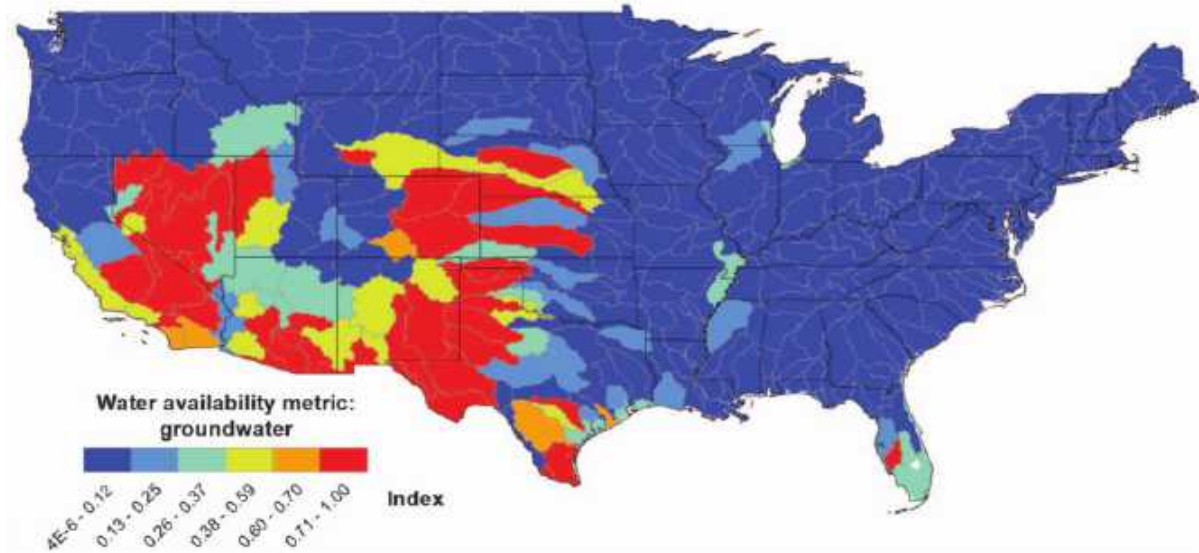
Source: UCS 2011

# Limited Water Basins

Limited  
Surface Water

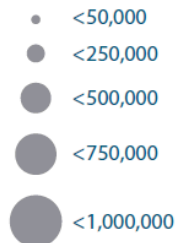


Limited  
Groundwater

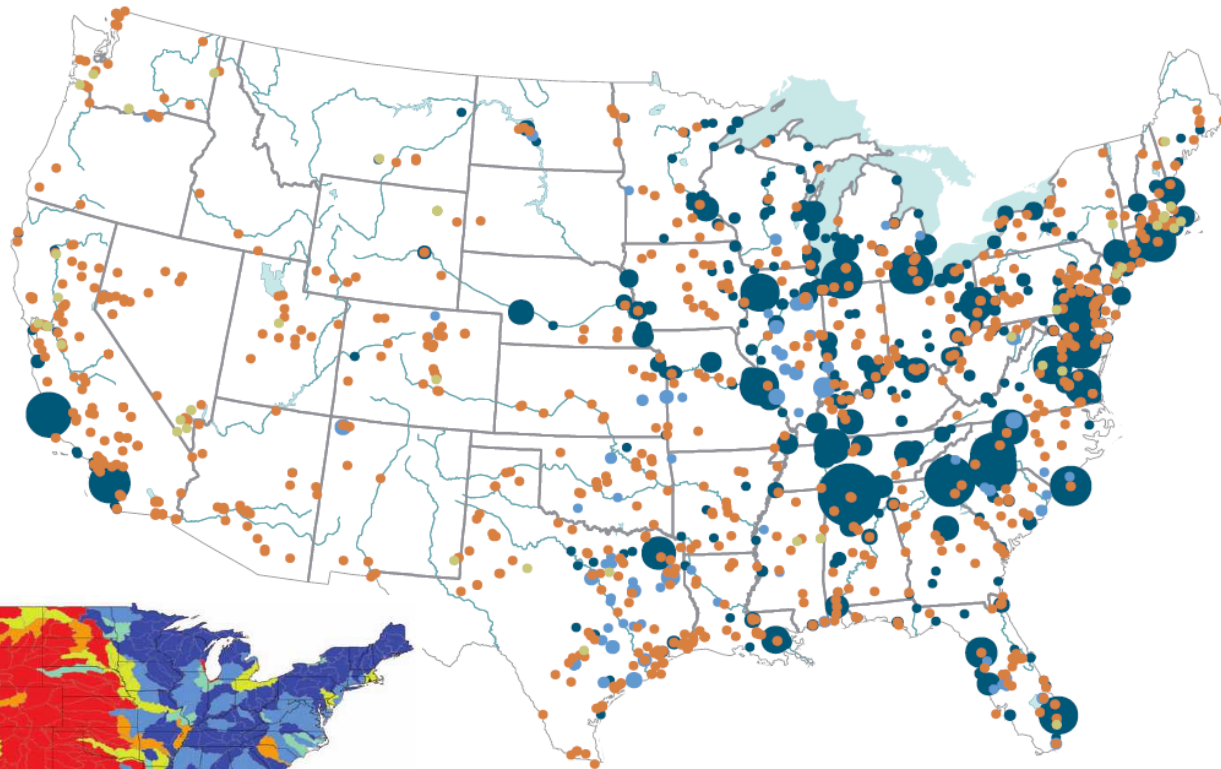
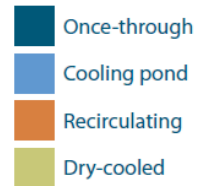


# Energy-Water Nexus

Withdrawal  
(millions of gallons/year)

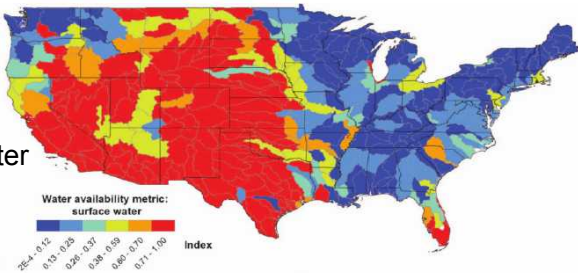


Cooling Technologies

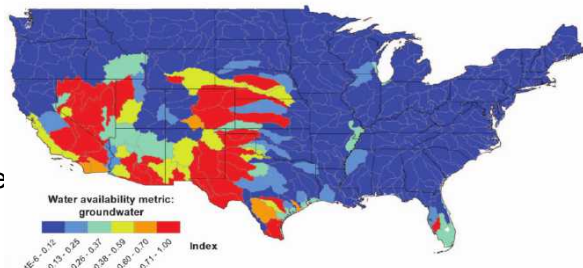


Source: UCS 2011

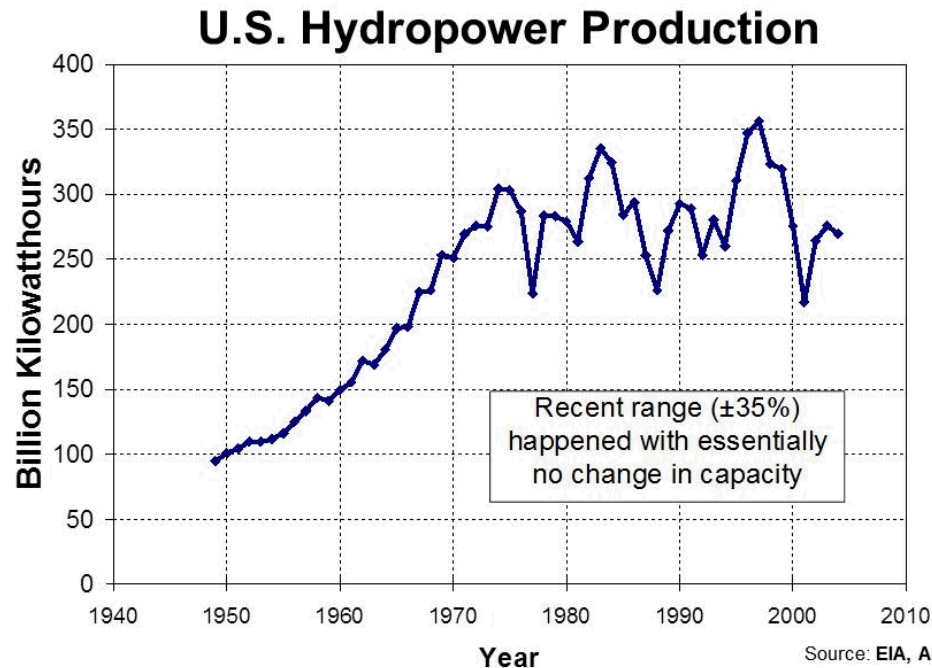
Surface Water  
Availability



Groundwater  
Availability



# Variability of Hydropower Production



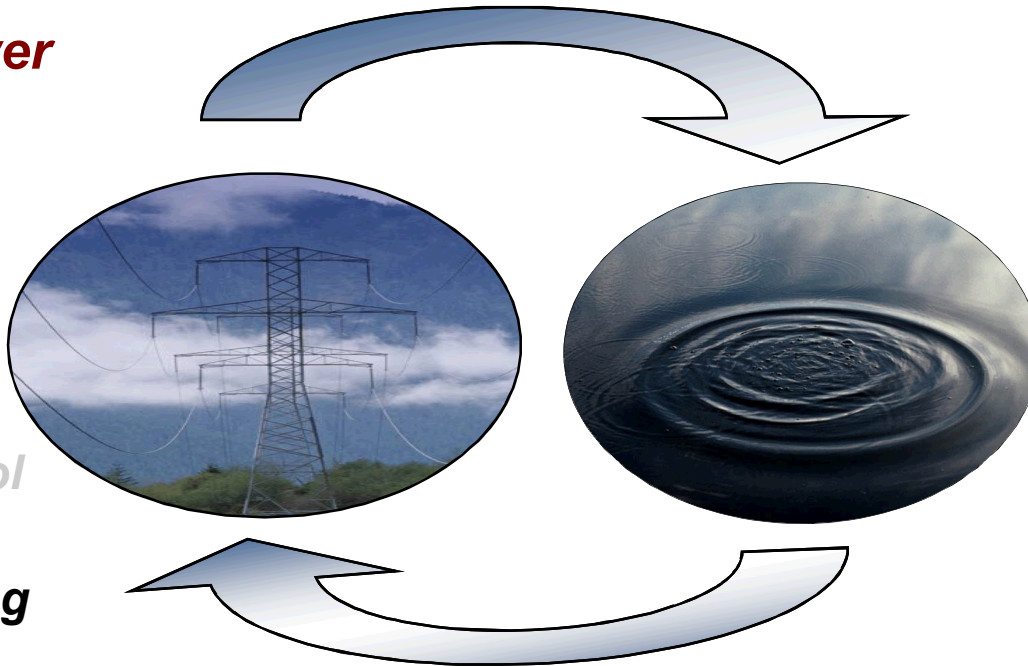
- Since 1980s, hydroelectric power has satisfied about 6% of the Nation's total electricity demand.
- Dispatchable renewable energy source often used to balance wind and solar production.
- 3,700 MW of generating capacity on the lower Colorado River is particularly vulnerable due to variety of issues.



# Energy-Water Nexus

## **Energy and power production requires water**

- *Thermoelectric Power Plant Cooling*
- *Emission Control*
- **Energy Minerals Extraction/Mining**
- **Fuel Processing (fossil fuels, H<sub>2</sub>, biofuels)**

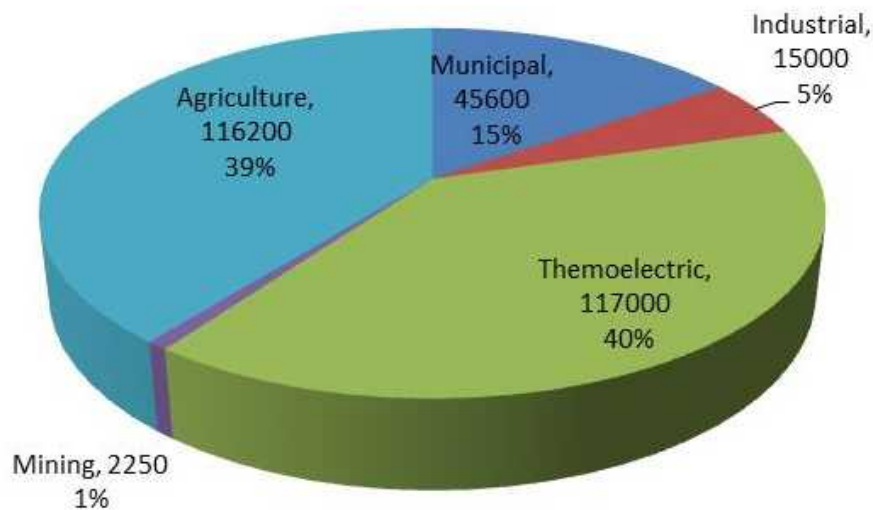


## **Water services require energy**

- *Pumping*
- *Conveyance*
- *Treatment*
- *Distribution*
- *Use Conditioning*

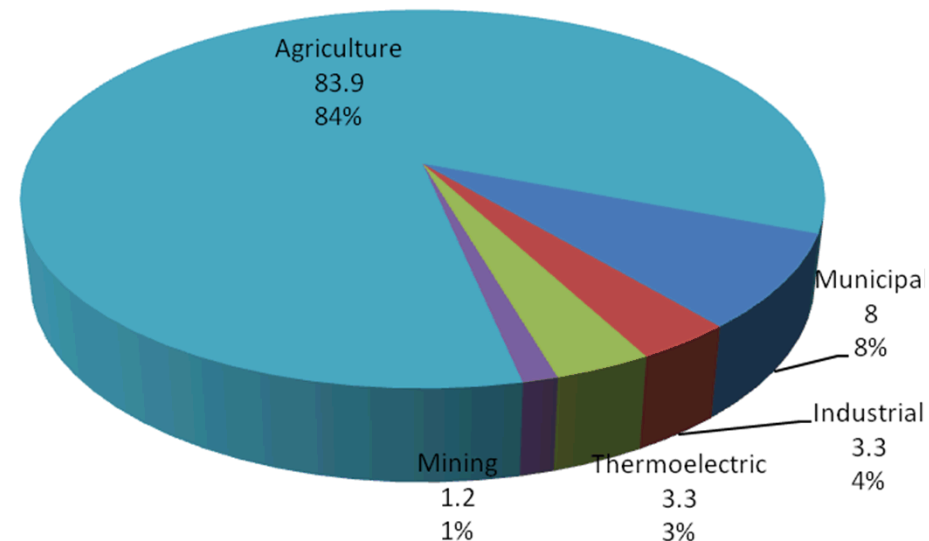
# Water for Mining and Fuel Processing

## Water Withdrawal (BGD) 2010



*Estimated at ~2.6 BGD consumed in mining and fuel processing*

## Water Consumption (BGD) 1995



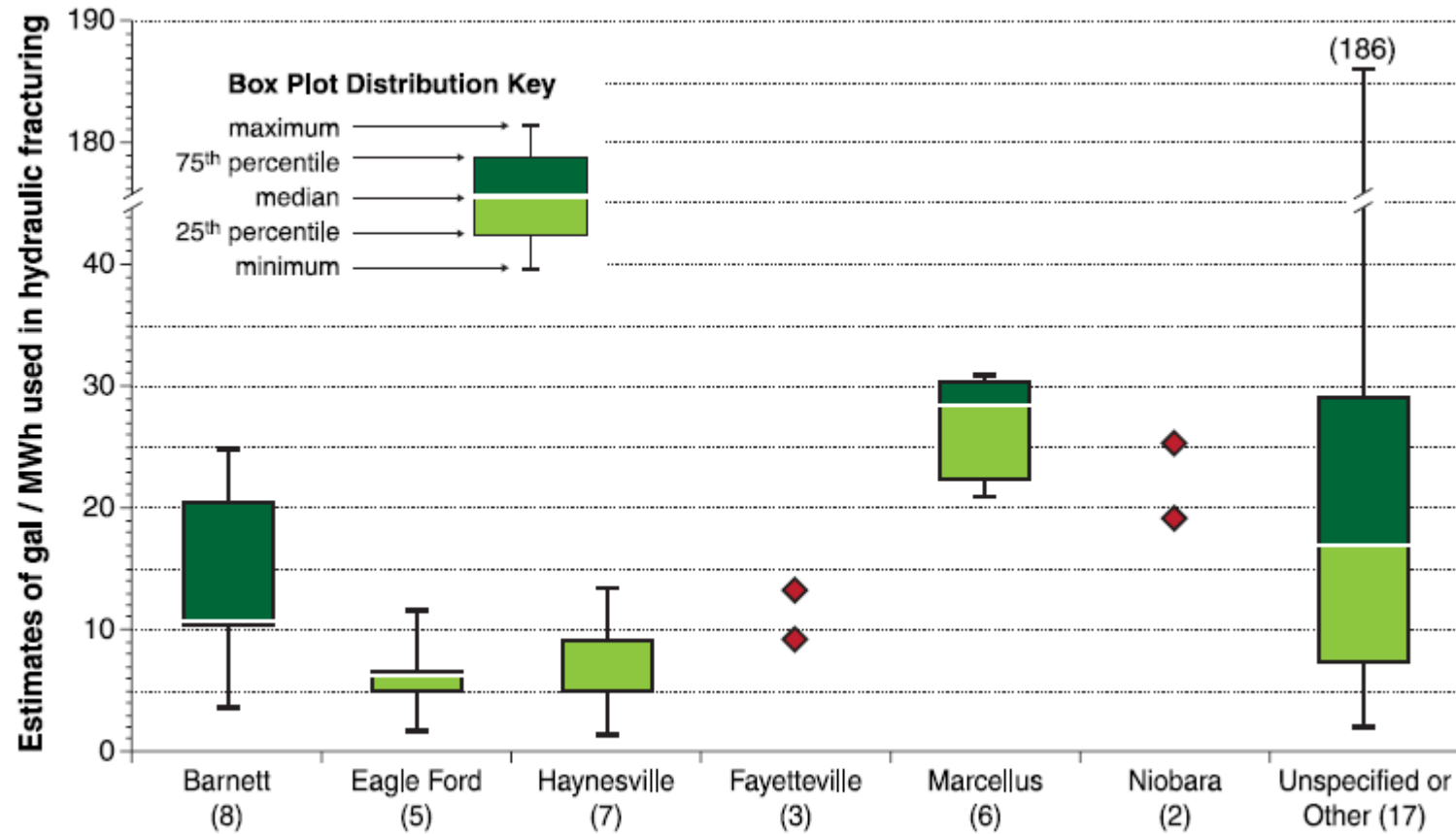
Source: USGS 1995, 2014

# Gas and Oil Shale Development





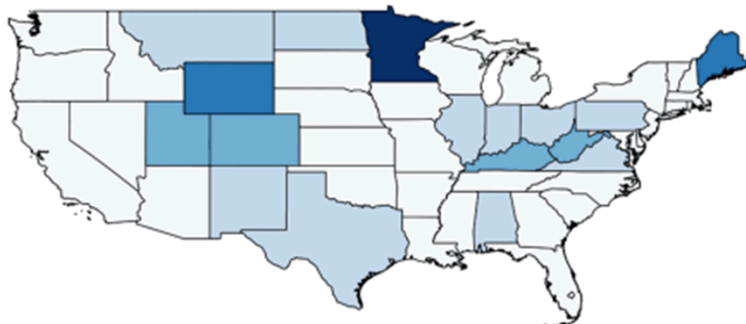
# Water Use in Hydraulic Fracturing



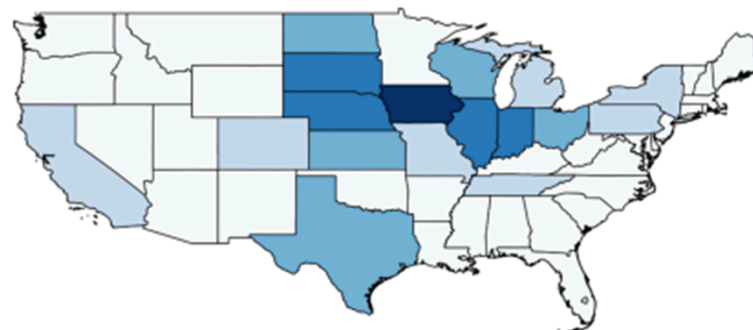
Source: Meldrum et al. 2013

# Water for Fuel Extraction

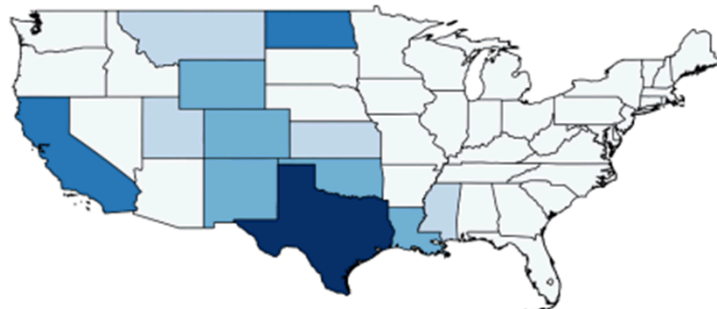
**Effect of Energy on Water: Coal**



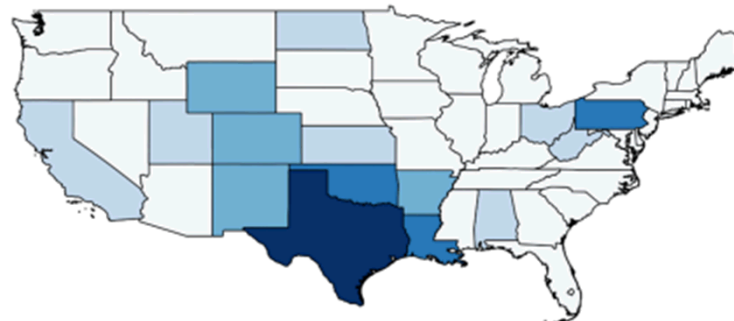
**Effect of Energy on Water: Ethanol**



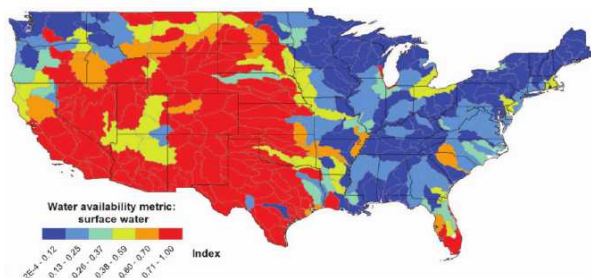
**Effect of Energy on Water: Oil**



**Effect of Energy on Water: Natural Gas**



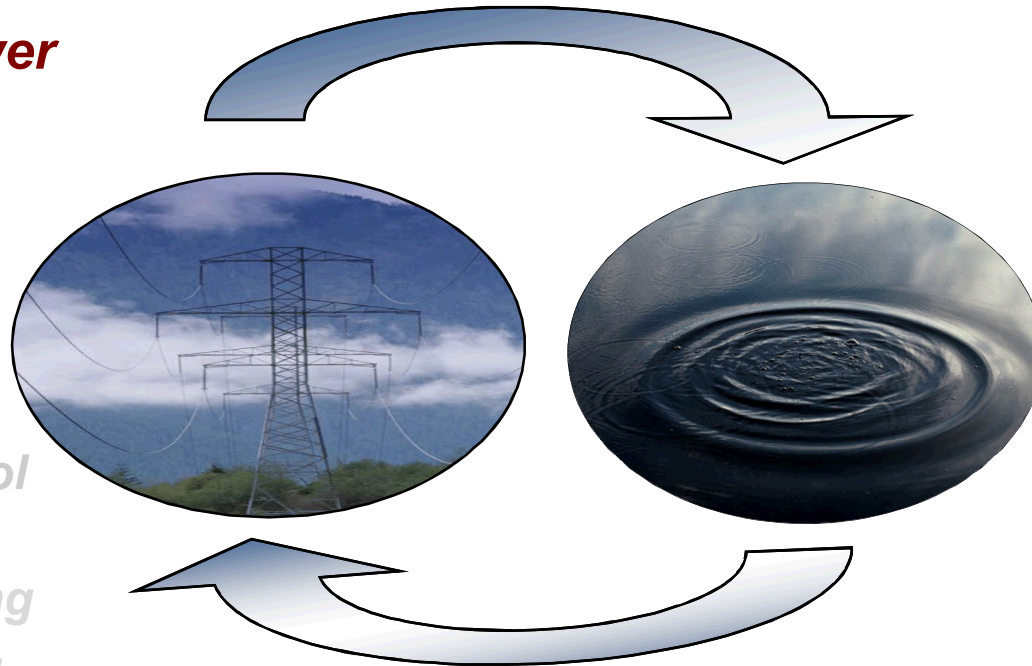
**Limited Surface Water**



# Energy-Water Nexus

## **Energy and power production requires water**

- *Thermoelectric Power Plant Cooling*
- *Emission Control*
- *Energy Minerals Extraction/Mining*
- *Fuel Processing (fossil fuels, H<sub>2</sub>, biofuels)*

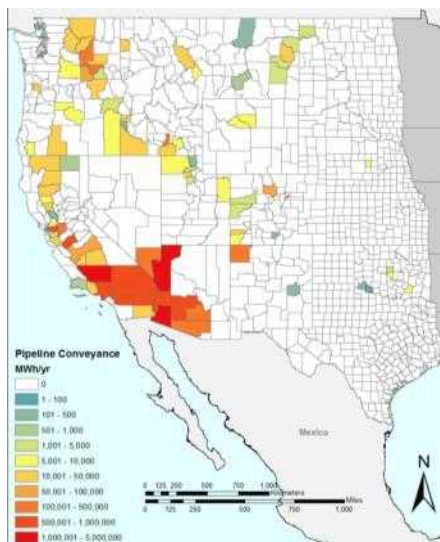


## **Water services require energy**

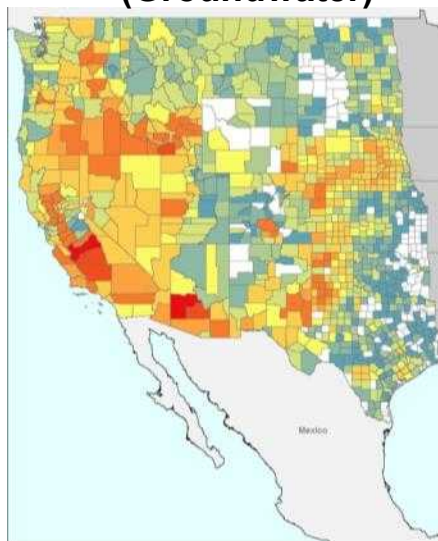
- *Pumping*
- *Conveyance*
- *Treatment*
- *Distribution*
- *Use Conditioning*

# Energy for Water

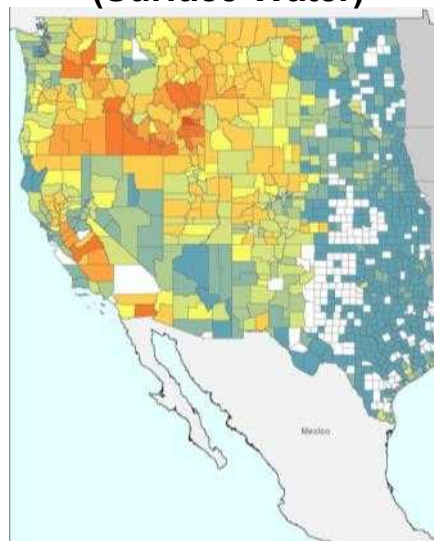
**Large-Scale Conveyance**



**Agricultural Pumping  
(Groundwater)**

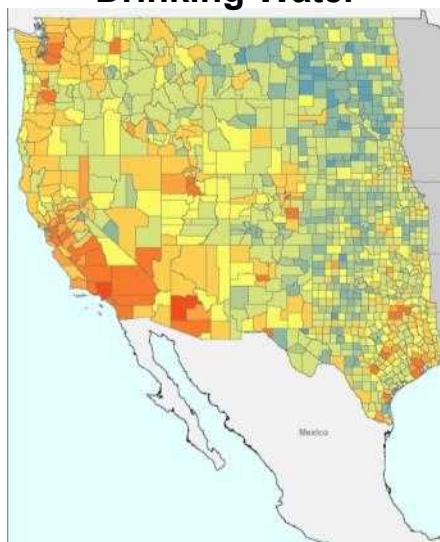


**Agricultural Pumping  
(Surface Water)**

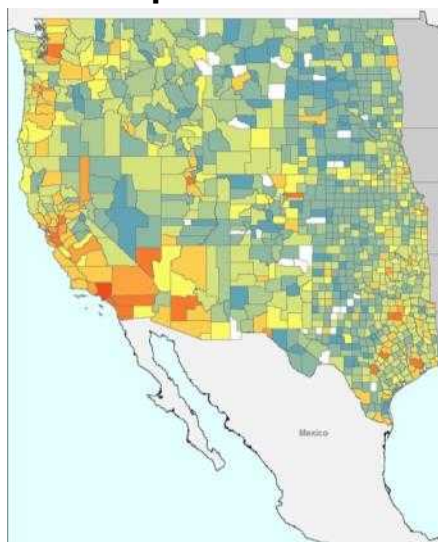


~6% of  
electricity use  
goes to  
providing  
water services.

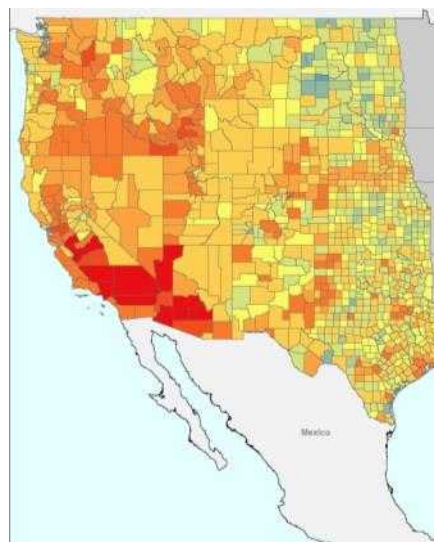
**Drinking Water**



**Municipal Wastewater**



**All Water Services**

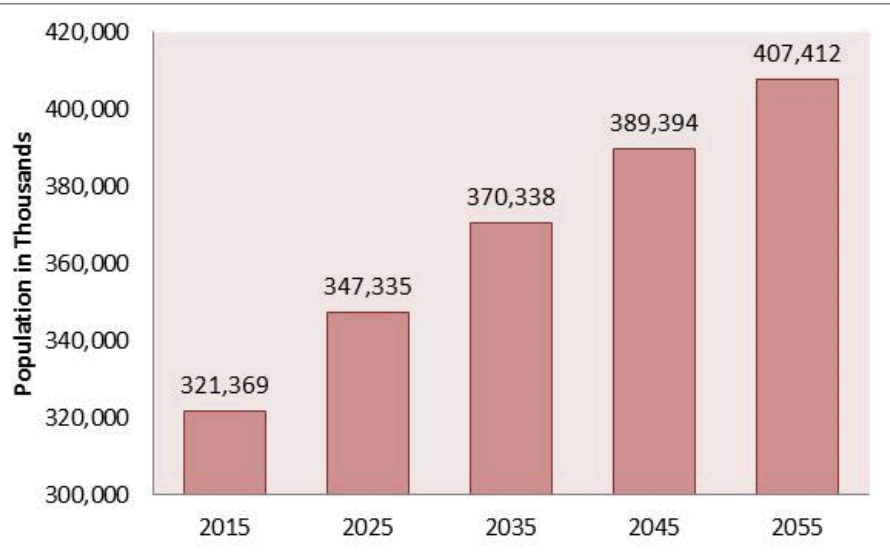


Source: Tidwell et al. 2014

***Energy-  
Water  
Nexus  
Future***



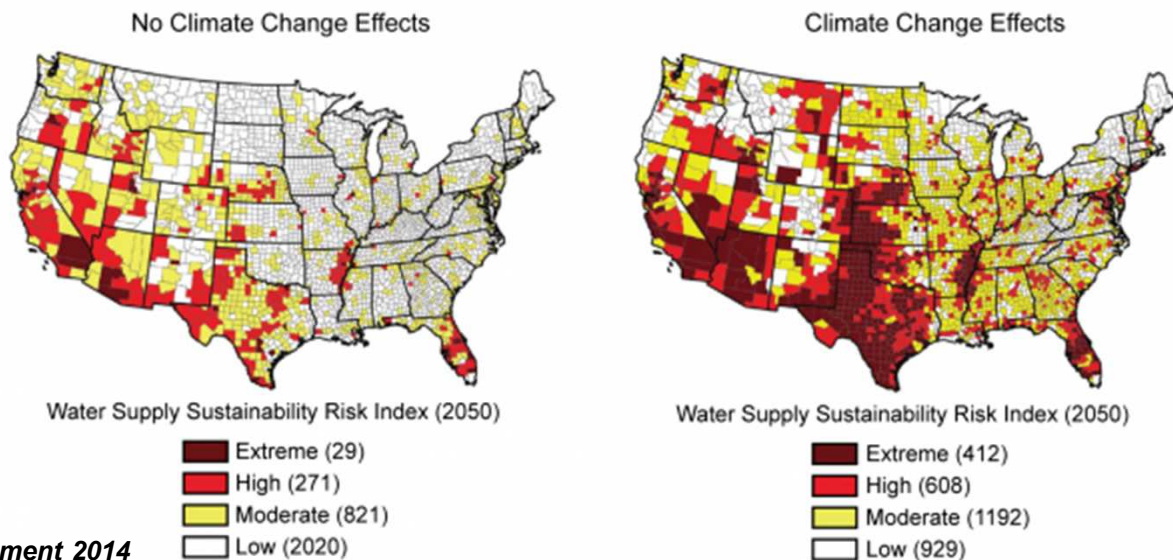
# Growth and Change



Source: U.S. Census Bureau 2014

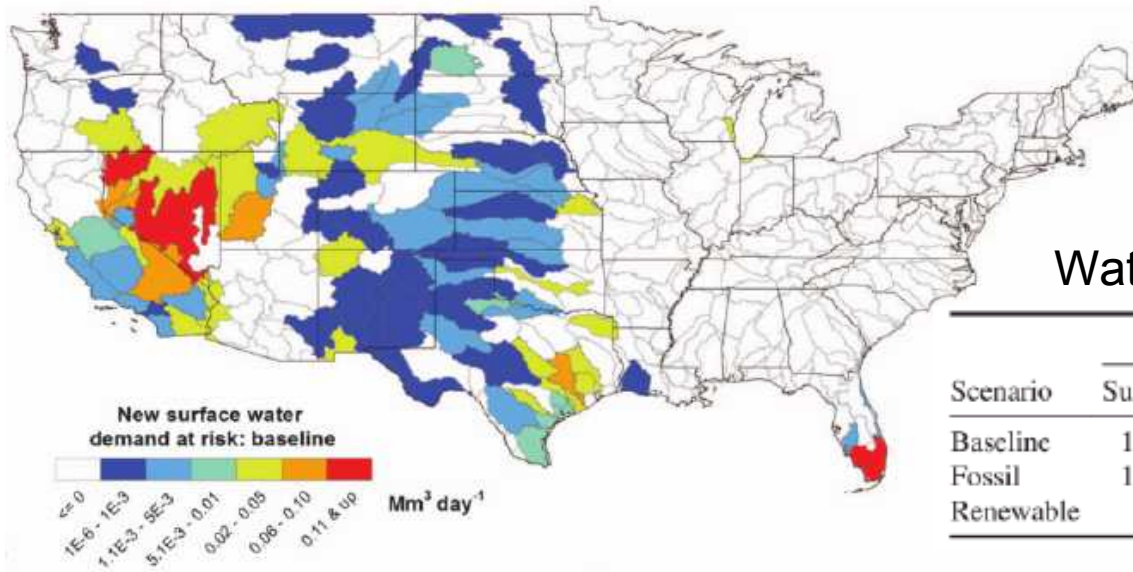
## Growing Population & Climate Change

Water Supplies Projected to Decline



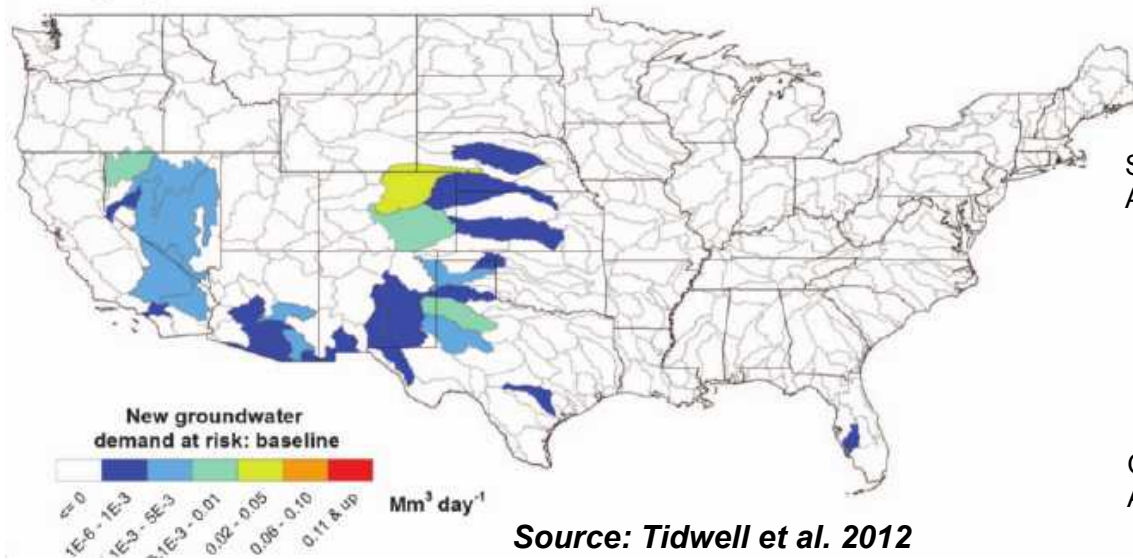
Source: National Climate Assessment 2014

# Thermoelectric Development in Water Limited Basins

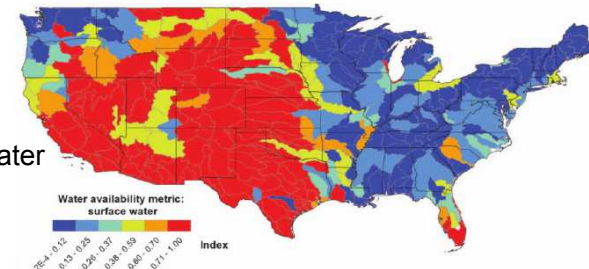


## Water and Power at Siting Risk

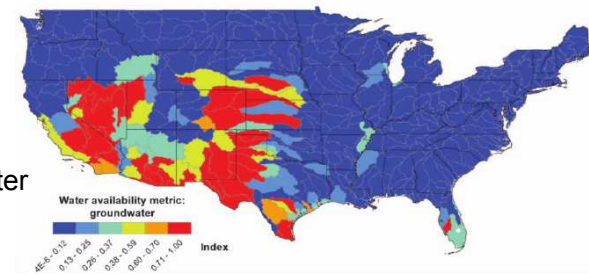
Scenario	Power (MMWh)		Water ( $\text{Mm}^3/\text{day}$ )	
	Surface water	Ground water	Surface water	Ground water
Baseline	163 (18%)	11 (1%)	1.18 (24%)	0.06 (1%)
Fossil	139 (15%)	19 (2%)	1.24 (23%)	0.10 (2%)
Renewable	84 (9%)	5 (0.5%)	0.85 (19%)	0.04 (1%)



## Surface Water Availability



## Groundwater Availability



Source: Tidwell et al. 2012

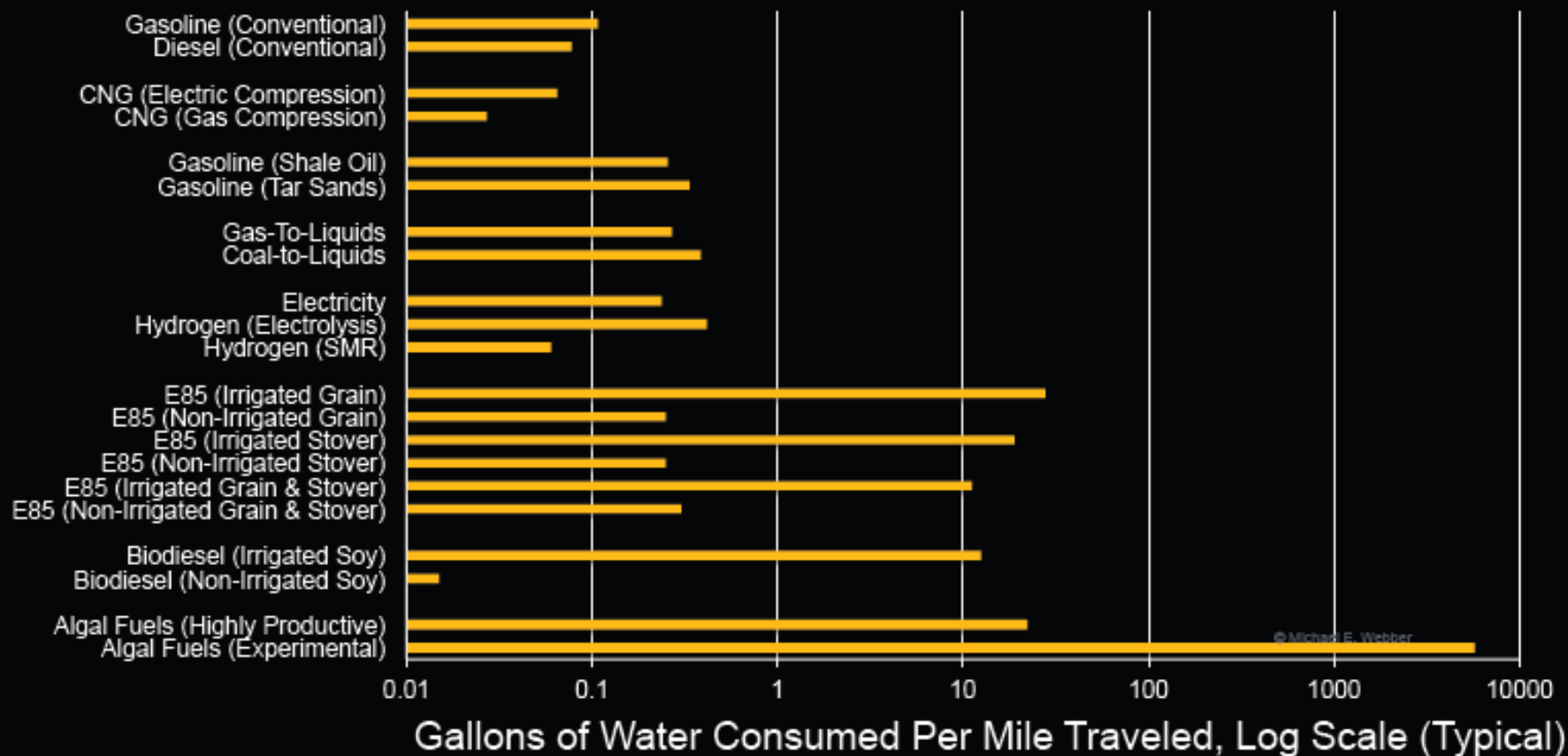


# Water for Transportation Fuels

## Water Intensity of Transportation

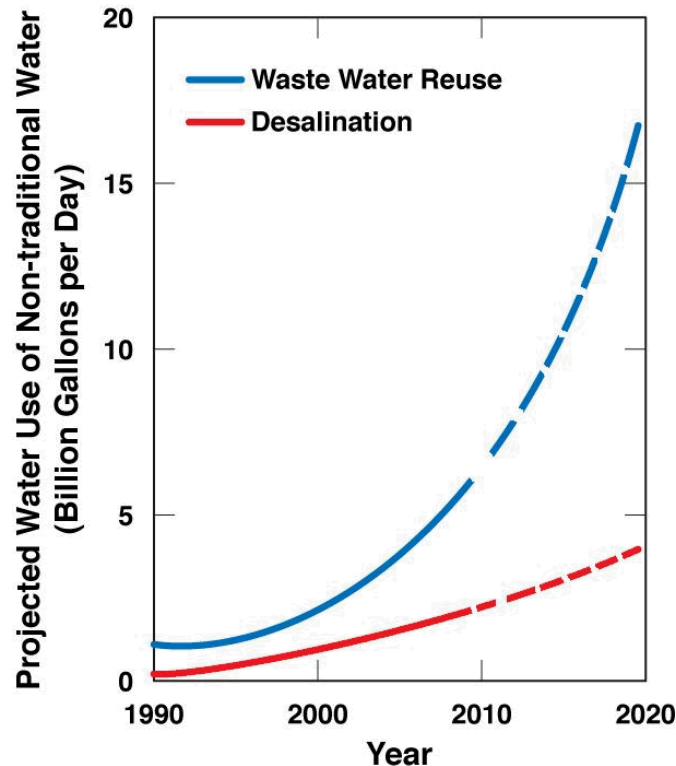
Source: Recreated from King & Webber (2008) and Twomey, Beal, King & Webber (2012)

Graphic: Michael E. Webber, The University of Texas at Austin

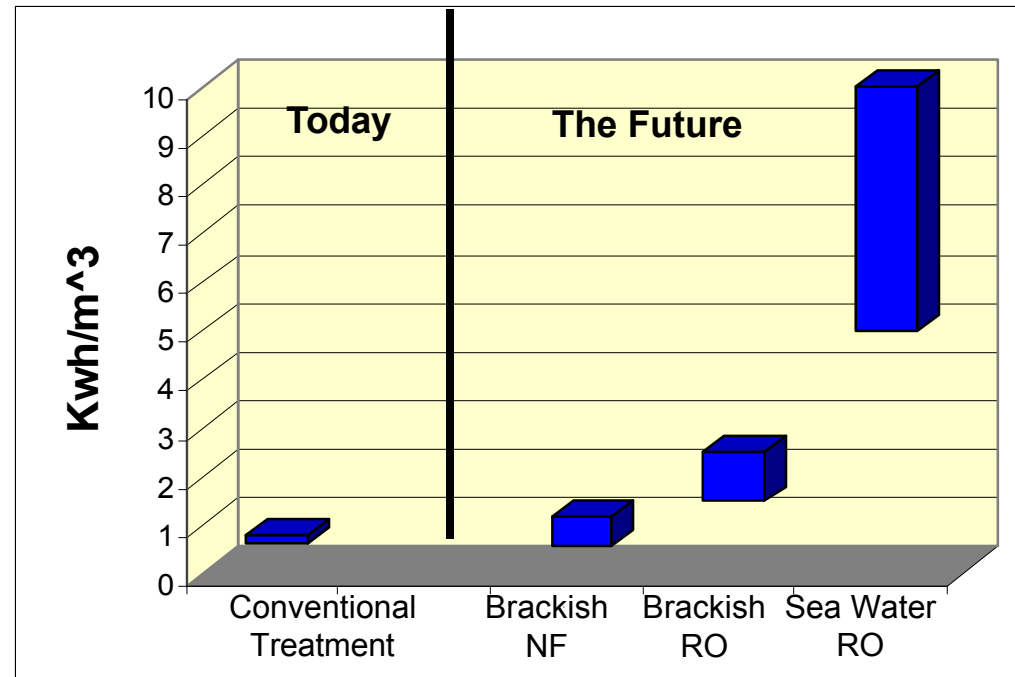


# Energy for Water

## *Power Requirements For Treatment*



(Modified from Water Reuse 2007, EPA 2004, Mickley 2003)



(Einfeld 2007)

- Desal growing at 10% per year, waste water reuse at 15% per year
- Non-traditional water use is energy intensive

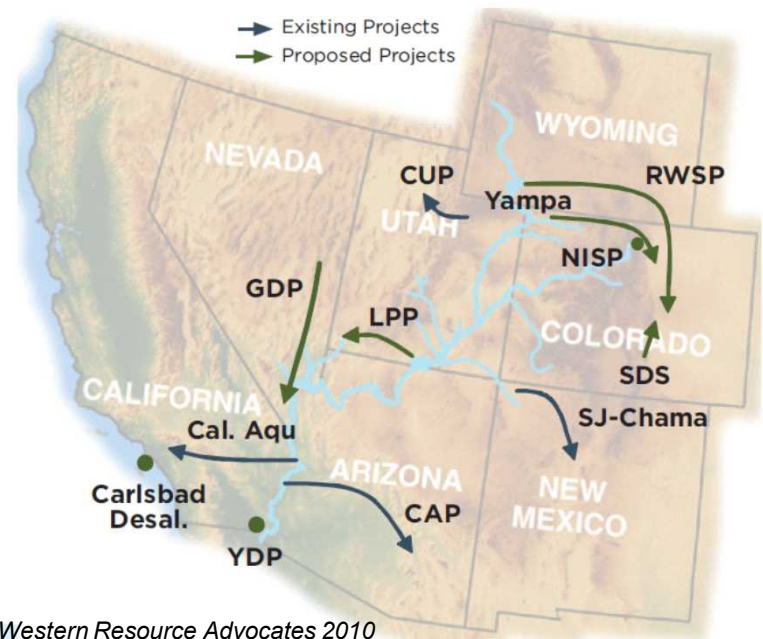
# Energy for Water

- EPA is struggling with regulating pharmaceuticals in our Nation's drinking water.
- Treatment technologies for removing these contaminants at these concentrations are energy intensive.
- Numerous pipelines for trans-basin water transfers are in the planning and construction stage.



Source: [detoxifynow.com](http://detoxifynow.com)

*Existing and Proposed Western Water Supply Projects*



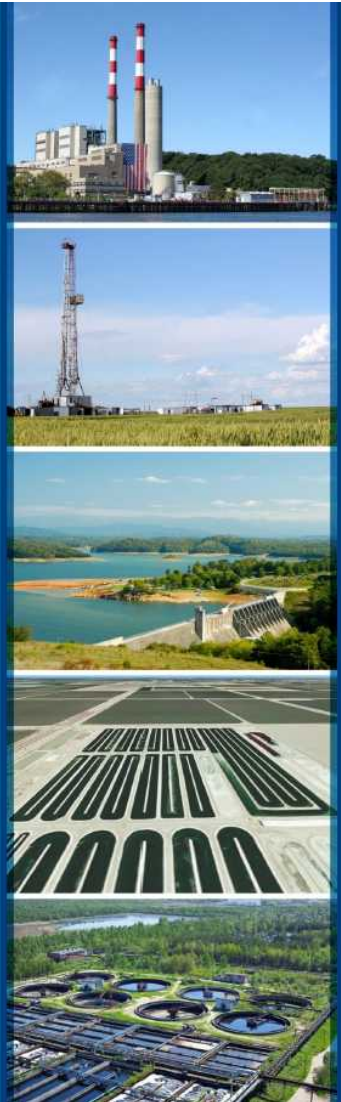
***Energy-  
Water  
Nexus  
Solutions***

# Water-Energy Nexus Report

## The Water-Energy Nexus:

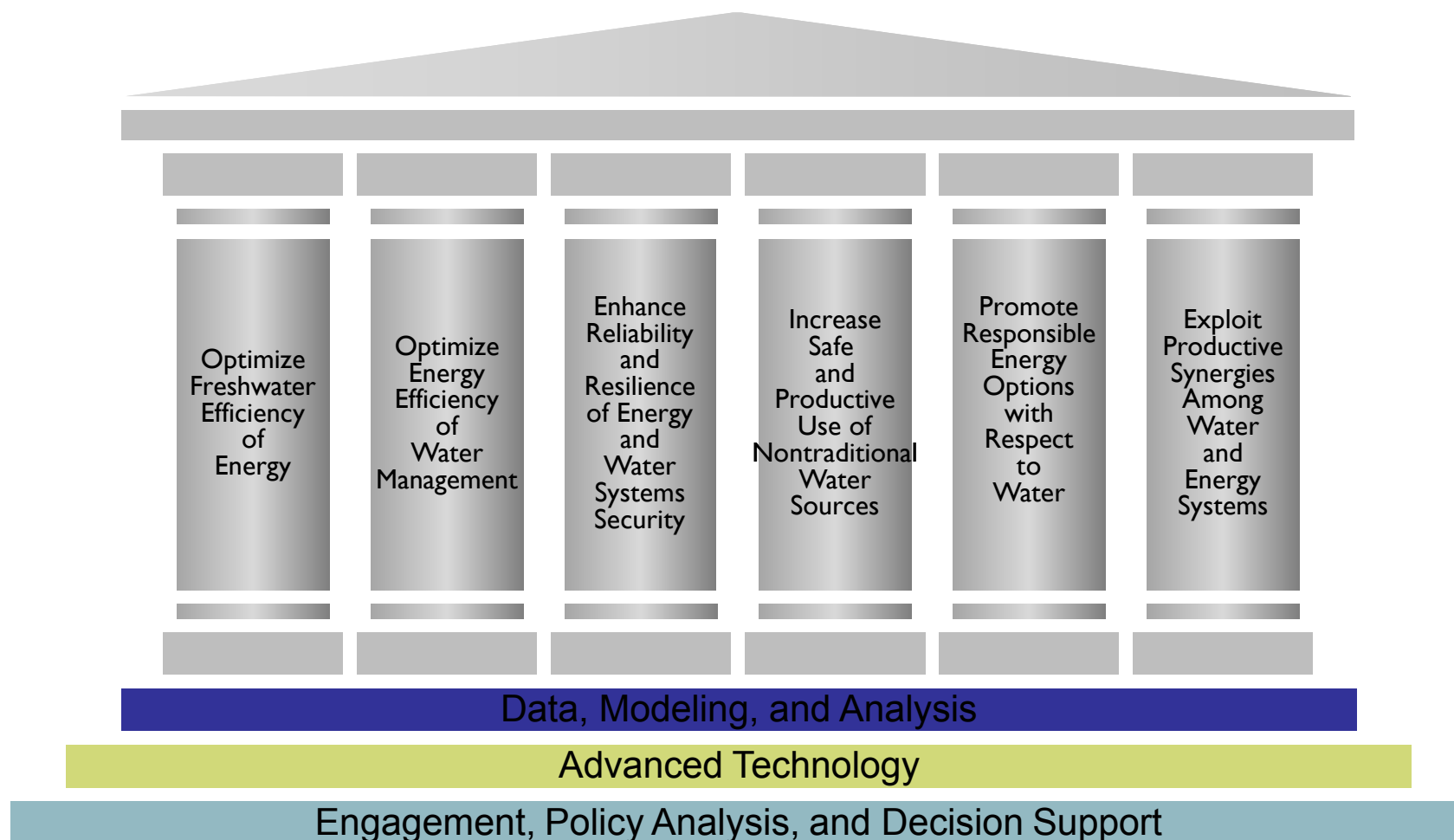
Challenges and  
Opportunities

June 2014



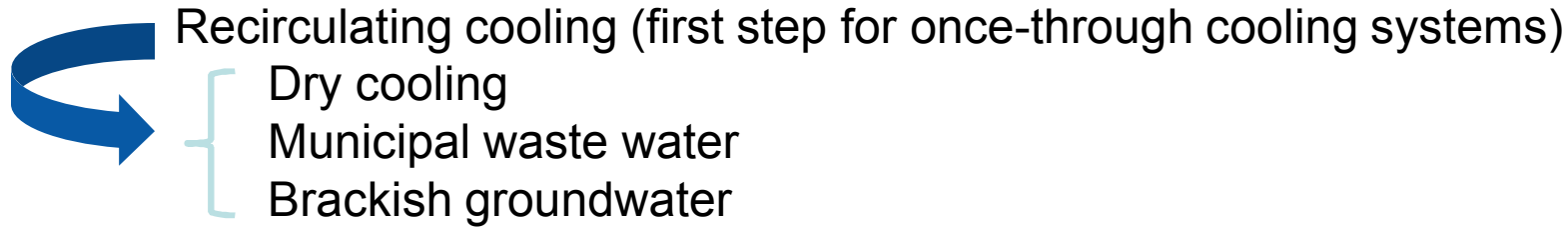
- Prepared by the Department of Energy
- Released June 2014
- Purpose:
  - Provides a foundation for future DOE action,
  - Provide data and analysis to frame opportunities, and
  - Broadly engage others in the dialogue.

# Goals



# Transitioning to Zero Freshwater Withdrawal

**Retrofits considered:** *average difficulty, according to EPA guidelines*



## **Costs:**

Capital

Operating and Maintenance (O&M) costs

Capture (e.g., conveyance costs for waste water, drilling and pumping costs for brackish groundwater)

Treatment

Parasitic energy losses

## **Availability:**

Municipal waste water: within 50 miles

Brackish water: <2500 ft deep, salinities >10,000 TDS

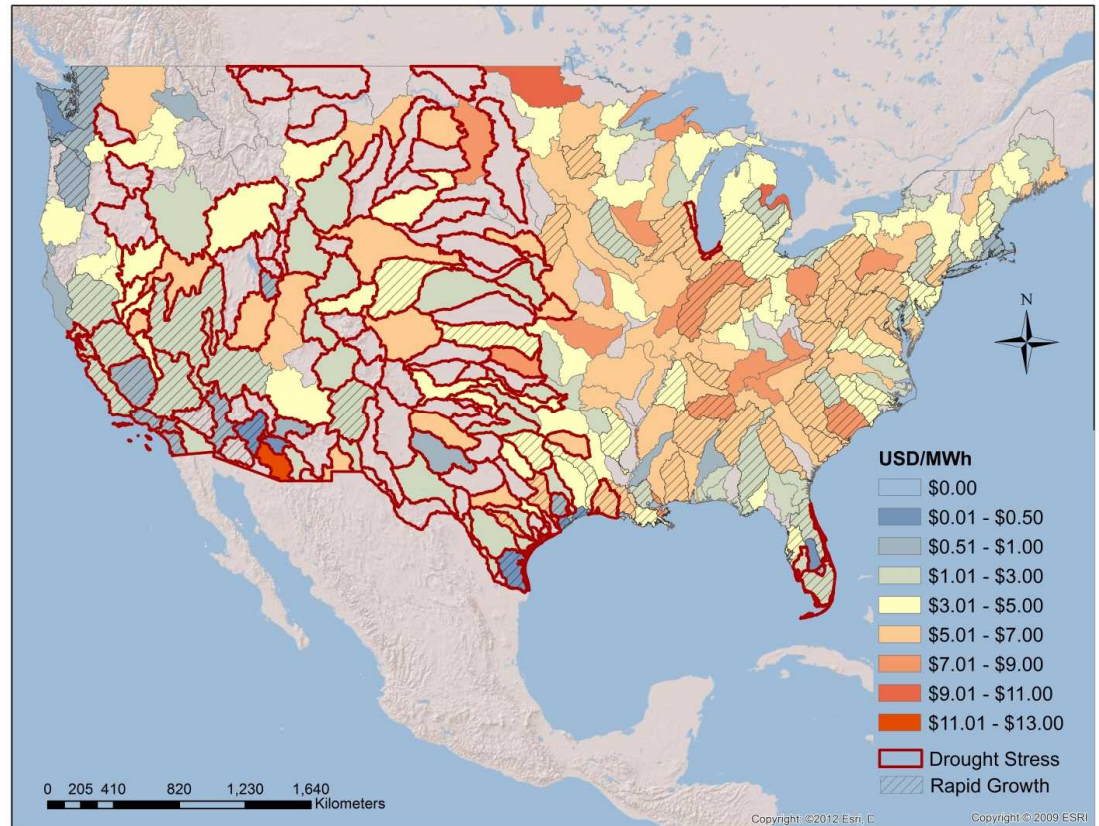
\* NOTE: not taking into consideration site-specific constraints such as land availability, local regulations, technology vintage



# Opportunities for Retrofit

Technology	Number of plants
Waste water	823
Brackish water	109
Dry cooling	246

Note:  $\Delta$ LCOEs tend to be lower in the West, Texas Gulf Coast and south Florida, which are areas prone to drought stress



Source: Tidwell et al. 2014

*With wholesale cost of electricity about \$40/MWh\*, many retrofits could be accomplished at levels that would add less than 10% to current power plant generation expenses.*

\*average 2012 wholesale cost over 3 US trading hub regions

# Transmission Planning

- WECC and ERCOT are conducting long-range transmission planning (20 yrs.) to direct:
  - Siting of new power plants
  - New transmission capacity



WESTERN  
GOVERNORS'  
ASSOCIATION

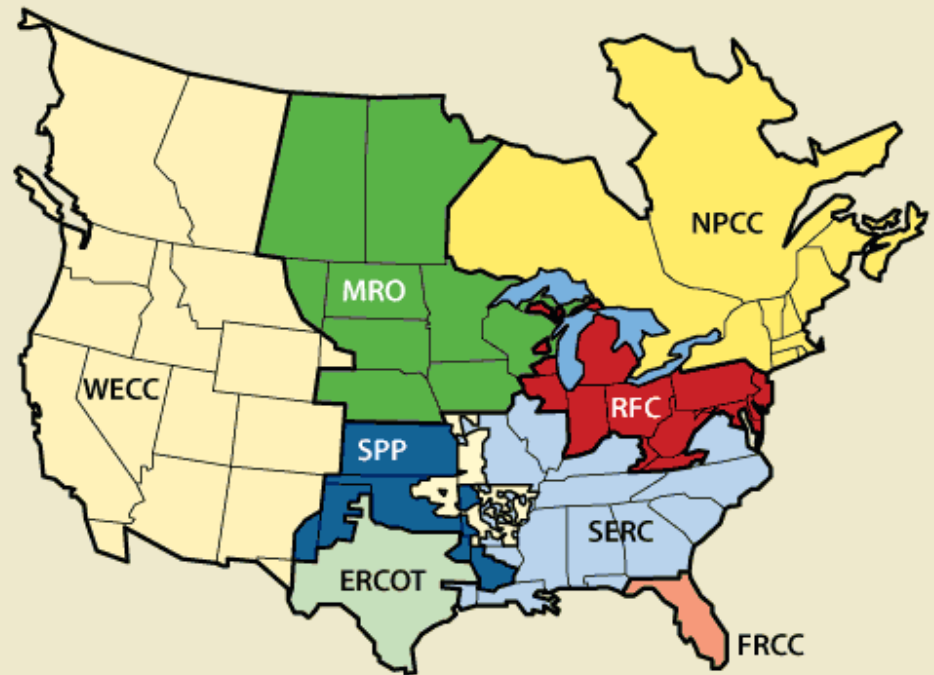
*Serving the Governors of 19 States and 3 US-Flag Pacific Islands*



WSWC

Western States Water Council

## The North American Electric Reliability Corporation Regions

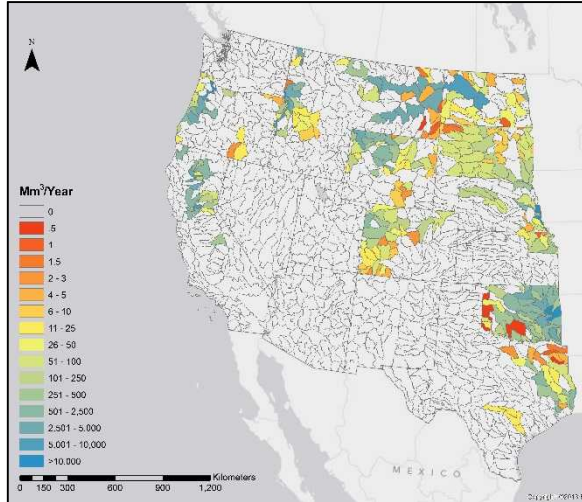


Source: North American Energy Reliability Corporation.

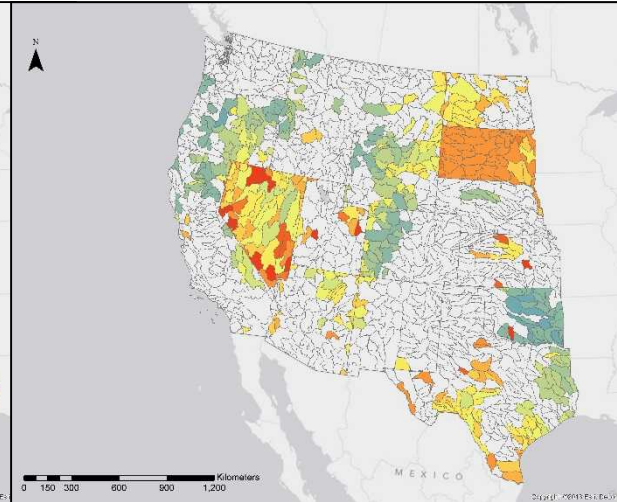


# Water Availability and Future Demand

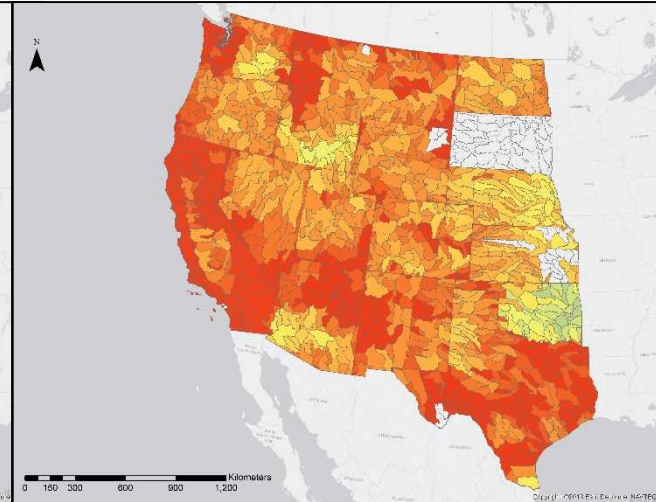
Unappropriated Surface Water



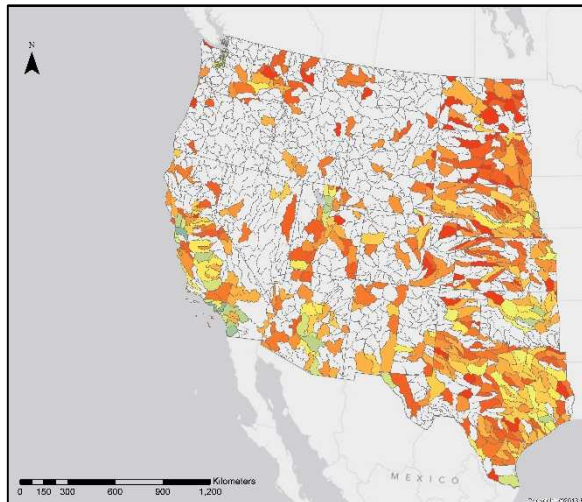
Unappropriated Groundwater



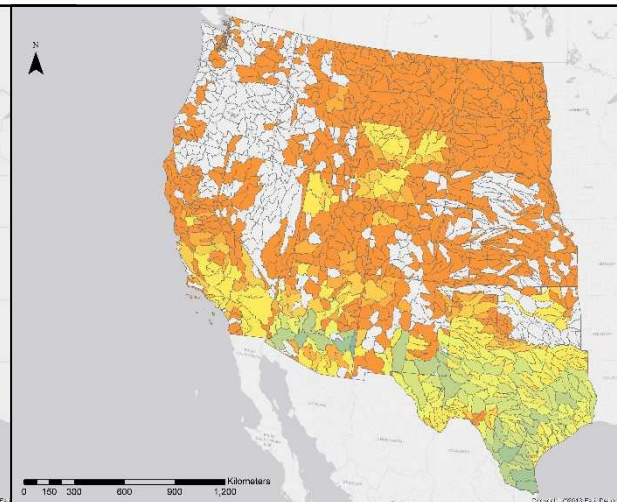
Appropriated Water



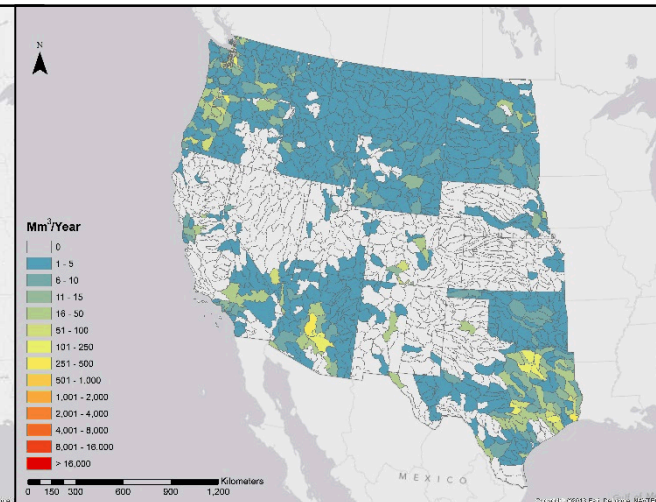
Municipal Wastewater



Brackish Groundwater

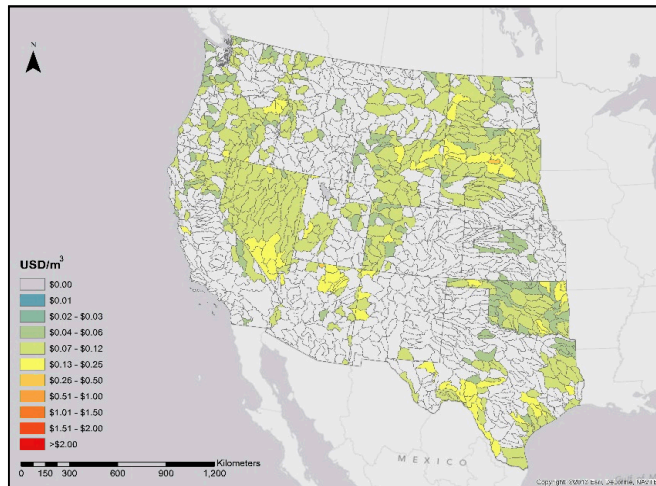


Consumptive Demand 2010-2030

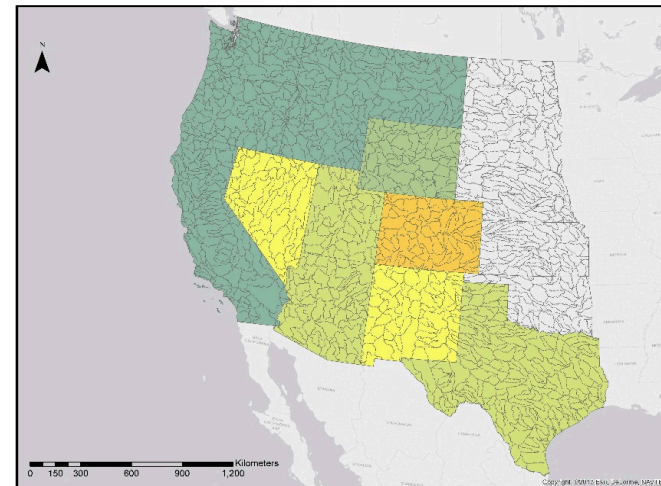


# Relative Cost of Water

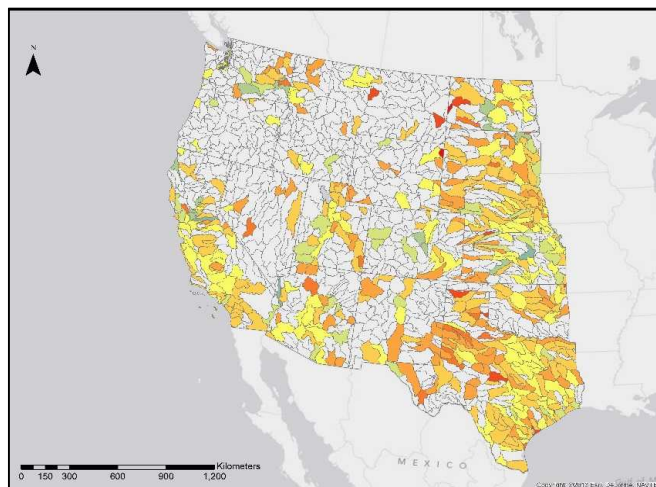
## Unappropriated Groundwater



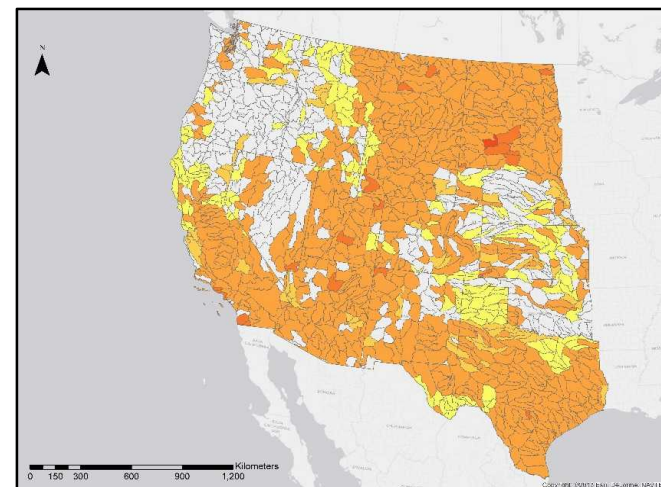
## Appropriated Water



## Municipal Wastewater

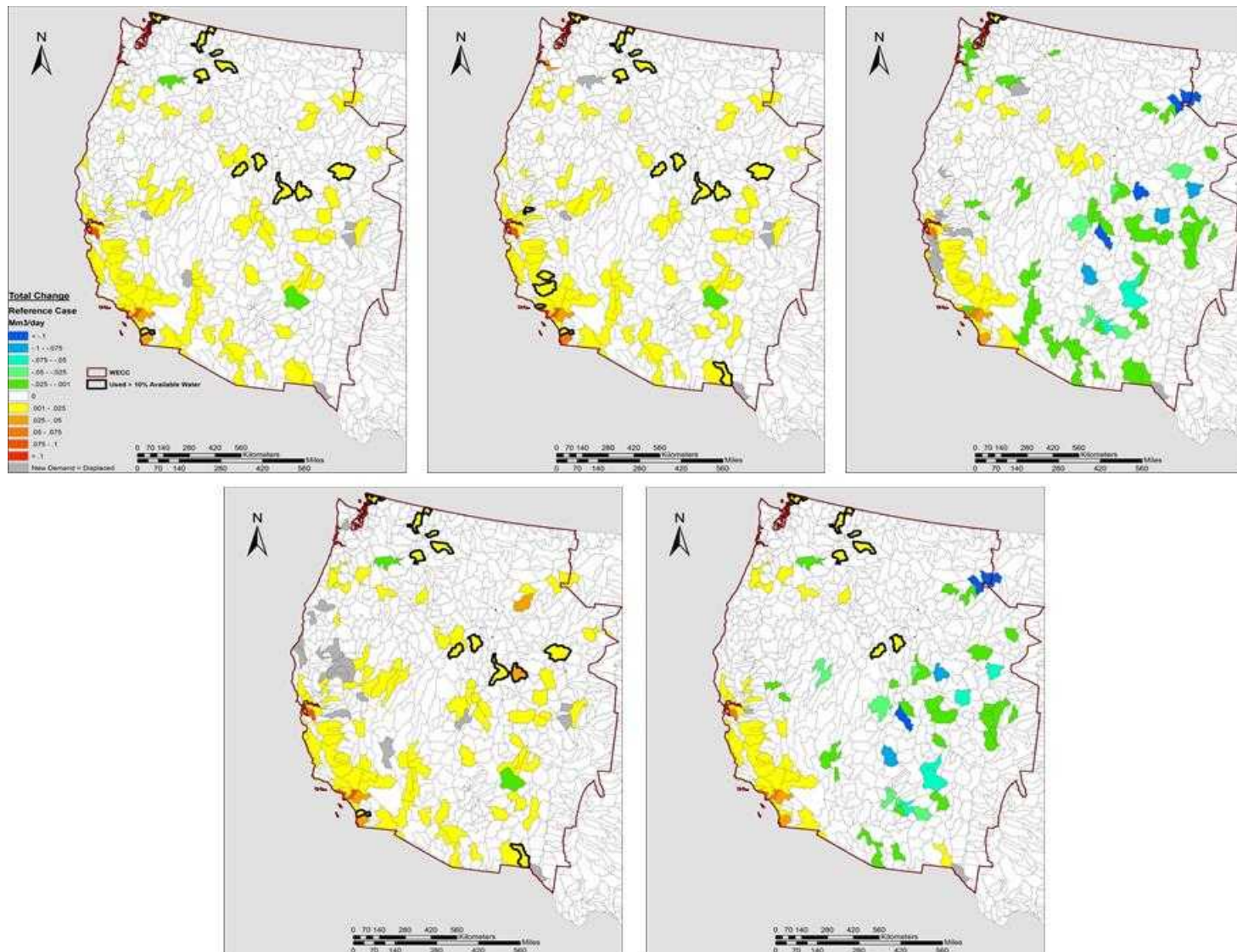


## Brackish Groundwater



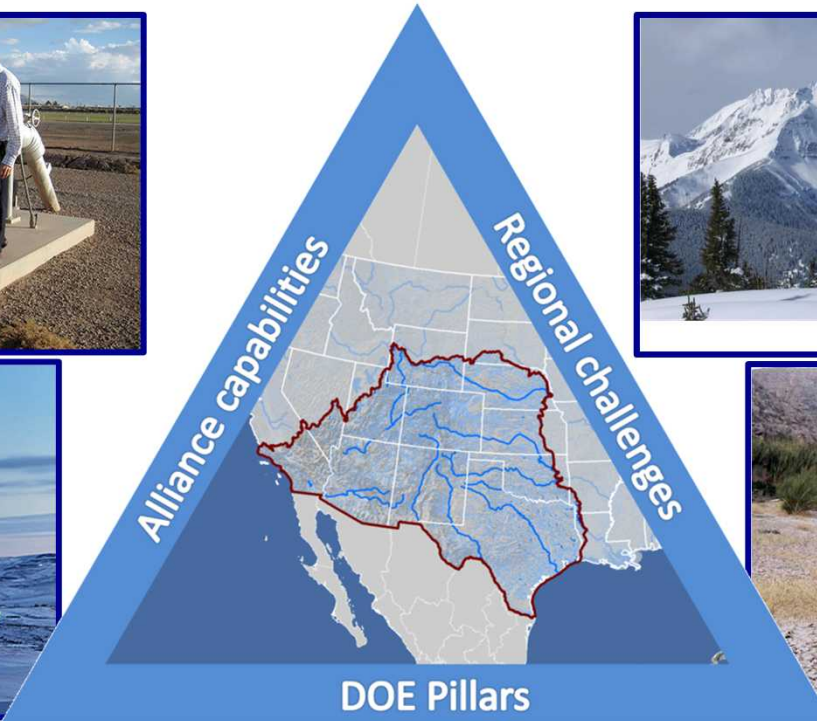


# Change in Thermoelectric Water Use





# Southwest & Southern Rocky Mountain Water-Energy Nexus Alliance

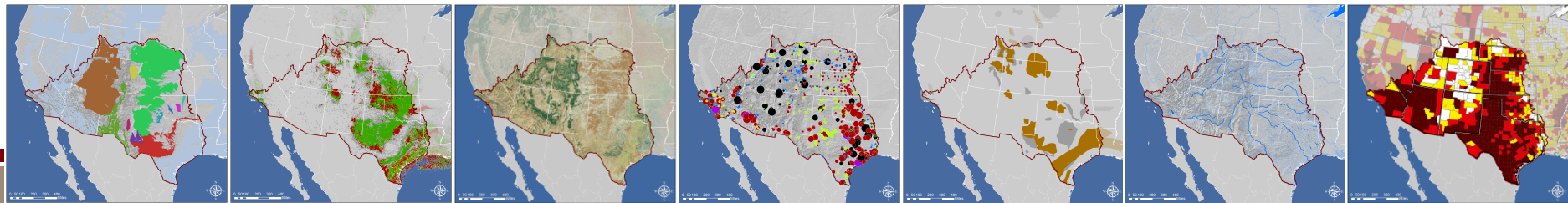


# Total Water-Energy Management

## *Mission (Draft):*

*With sparse and near-fully subscribed water availability in the SWSRM region, this alliance will focus on integrating modeling and data analysis capabilities, advancing deployable technologies, and actively engaging stakeholders to enable optimal planning and management of regional water and energy resources in these theme areas:*

- Climate and Integrated Water-Energy Systems
- Produced and Alternative Water Supplies
- Energy for Desalination and Transport of Water Supplies
- Hybrid Cooling Technology to Reduce Water Requirements



# Summary

- The energy sector withdrawals more water than any other sector in the US
  - Power plant cooling
  - Fuel extraction
  - Fuel processing
- The water sector consumes 12.6% of all energy production
- Growth, changing technology, and climate change will put pressure on this energy-water nexus
- There are options to manage the nexus



■ Project data available at:  
[http://energy.sandia.gov/?page\\_id=1741](http://energy.sandia.gov/?page_id=1741)

Vincent Tidwell

Sandia National Laboratories

[vctidwe@sandia.gov](mailto:vctidwe@sandia.gov)

(505)844-6025

Sandia National Laboratories

Energy and Climate

RENEWABLE SYSTEMS CLIMATE/ENVIRONMENT ENERGY INFRASTRUCTURE ENERGY RESEARCH ABOUT EC

Energy and Climate • Climate/Environment • Water Security Program • Energy and Water in the Western and Texas Interconnects

### Energy and Water in the Western and Texas Interconnects

Background Objectives Tasks Benefits/Outcomes Collaborators Links Documents Data Portal

#### Water Scarcity Impacts Energy Production

In the United States the energy sector accounts for approximately 41% of daily fresh water withdrawals and 49% of total overall daily water withdrawals for the following energy-related uses:

- Hydroelectric power generation
- Thermoelectric power plant cooling and air emissions control
- Energy-resource extraction, refining, and processing



The Energy Information Administration projects the U.S. population will grow by **70 million people** between 2005 and 2030, increasing electric power demand by **50 percent** and transportation fuel demand by **30 percent**. This will require more water. Unfortunately, this growth in water demand is occurring at a time when the nation's fresh water supplies are seeing increasing stress from:

- Limitations of surface-water storage capacity
- Increasing depletion and degradation of ground water supplies
- Increasing demands for the use of surface water for in-stream ecological and environmental uses
- Uncertainty about the impact of climate variability on future water fresh surface and ground water resources


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- Water, Energy, and Natural Resource Systems
- Energy and Water in the Western and Texas Interconnects
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